

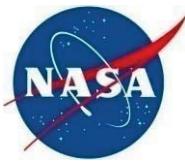
# James Webb Space Telescope Launch Window Trade Analysis

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Karen Richon (NASA GSFC)

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Laurel MD



# Agenda

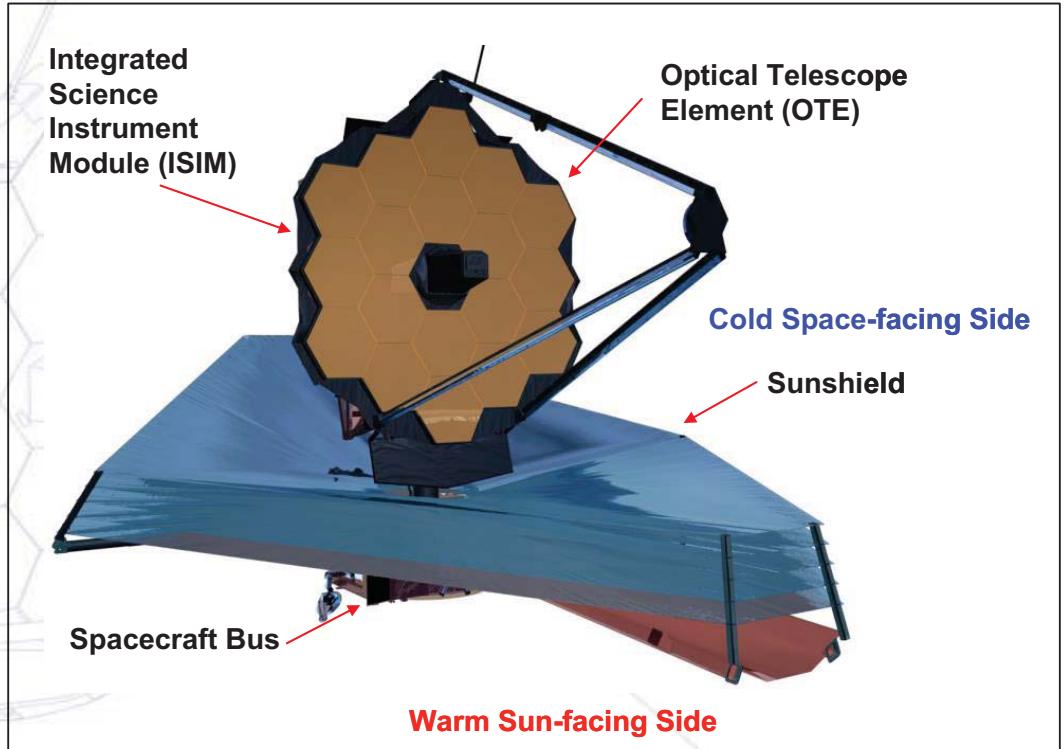
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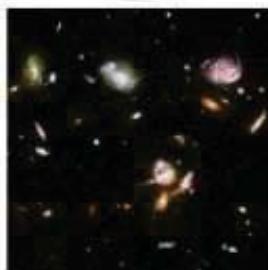
- **Introduction**
- **Overview of the James Webb Space Telescope**
- **Trajectory Design Requirements on Launch Window**
- **Unconstrained Launch Window**
- **Partially Constrained Launch Window**
- **Fully Constrained Launch Window**
- **Conclusions / Future Work**

# Introduction

- James Webb Space Telescope (JWST) is a deployable infrared telescope
- Orbit design is a Sun-Earth/Moon L2 Libration point orbit
- Nominal Launch Readiness Period: October 1<sup>st</sup> 2018 – Nov 30<sup>th</sup> 2018
  - This presentation studies the launch window in October 2018 from 11:30 – 14:00 UTC
- 10.5-year science mission goal



## JWST Science Themes



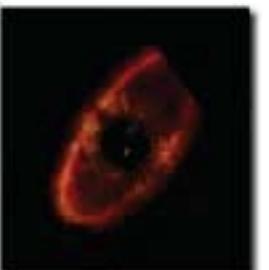
End of the dark ages: First light and reionization



The assembly of galaxies

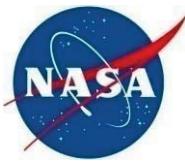


Birth of stars and proto-planetary systems



Planetary systems and the origin of life

What is the launch window that satisfies JWST subsystem derived constraints?



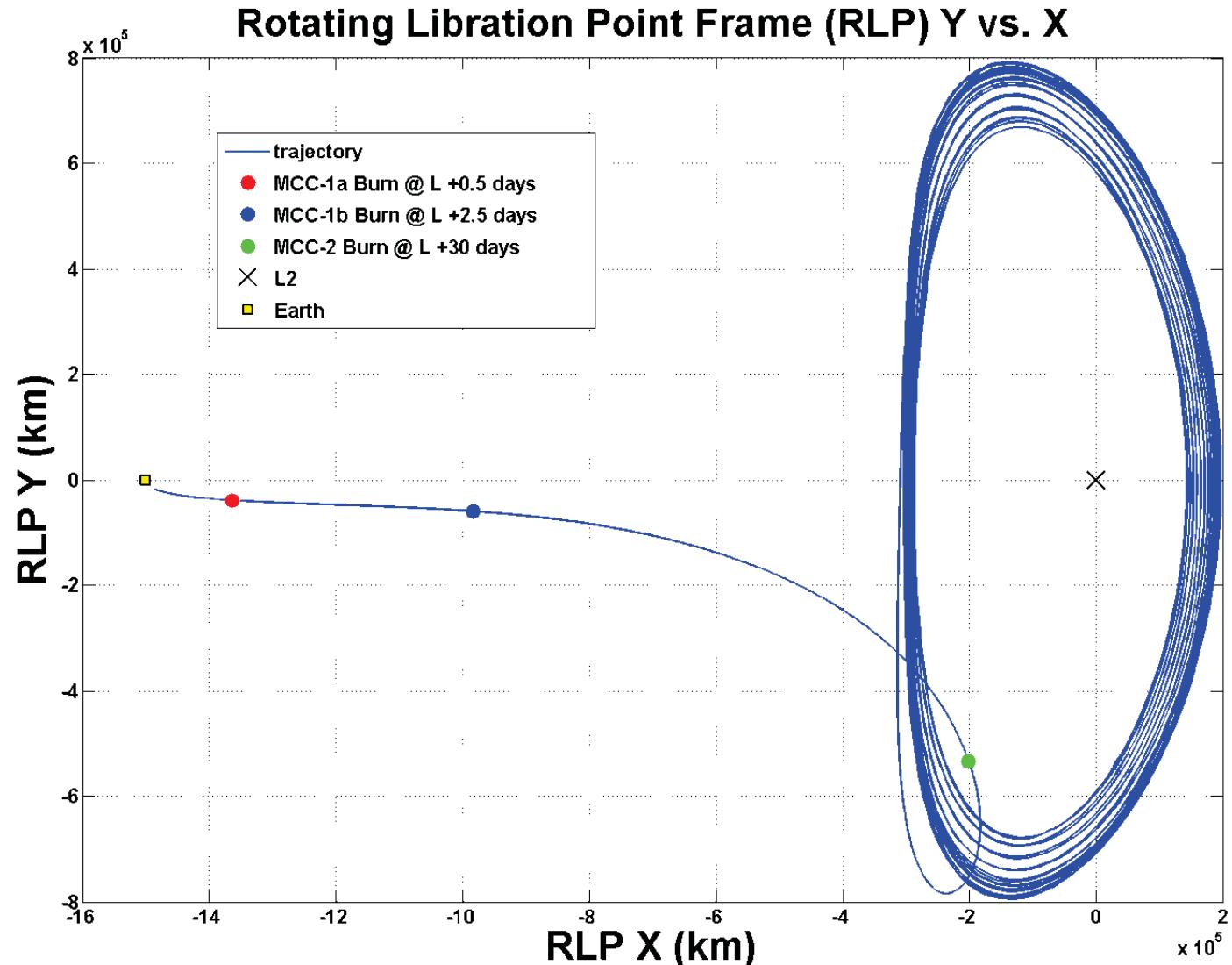
# Launch Vehicle



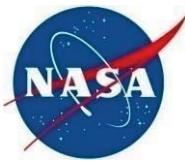
- European Space Agency-supplied Ariane 5 with the launch site at Kourou, French Guiana
- Injects JWST into a highly elliptical orbit with one of the given apogee altitudes below
- By design, energy from launch vehicle is not enough to achieve desired orbit
- JWST will perform three mid-course correction (MCC) maneuvers to transfer to the L2 libration point orbit

Designation	Apogee Altitude provided	C3 Energy Provided
Flight Program 1(FP1)	$1.02 * 10^6$ km	-0.7665 km <sup>2</sup> / s <sup>2</sup>
Flight Program 2(FP2)	$1.06 * 10^6$ km	-0.7381 km <sup>2</sup> / s <sup>2</sup>
Flight Program 3 (FP3)	$1.10 * 10^6$ km	-0.7117 km <sup>2</sup> / s <sup>2</sup>

The Ariane 5 vehicle can provide any of the three initial orbital energies for a given launch epoch to compensate for non-optimal launch times and dates



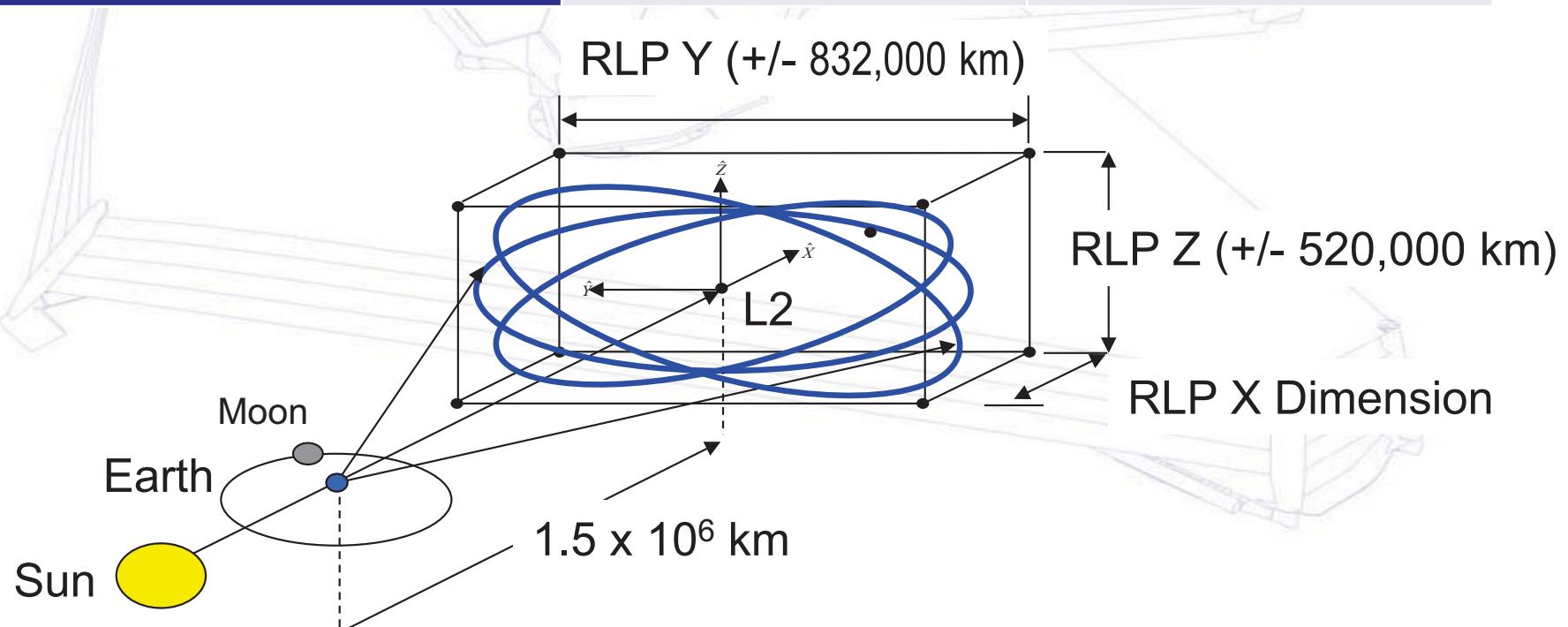
Three mid-course correction (MCC) maneuvers add to the launch vehicle's provided orbital energy so JWST will naturally fall into the Sun-Earth/Moon L2 Libration point orbit.

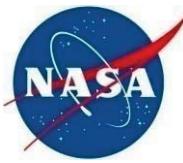


# Trajectory Design Requirements Affecting the Launch Window



Requirement/Constraint	Value	Requirements/ Constraint Driver(s)
MCC Maneuver Direction	RLP +X direction	Science
Available Mid-Course Correction (MCC) Maneuver $\Delta V$ for Nominal Injection	20.5 m/s - 38 m/s	Mass & Propulsion
Lunar / Earth Eclipse	None allowed	Power and Thermal
Rotating Libration Point (RLP) Size Requirements	See below	Science & Communication

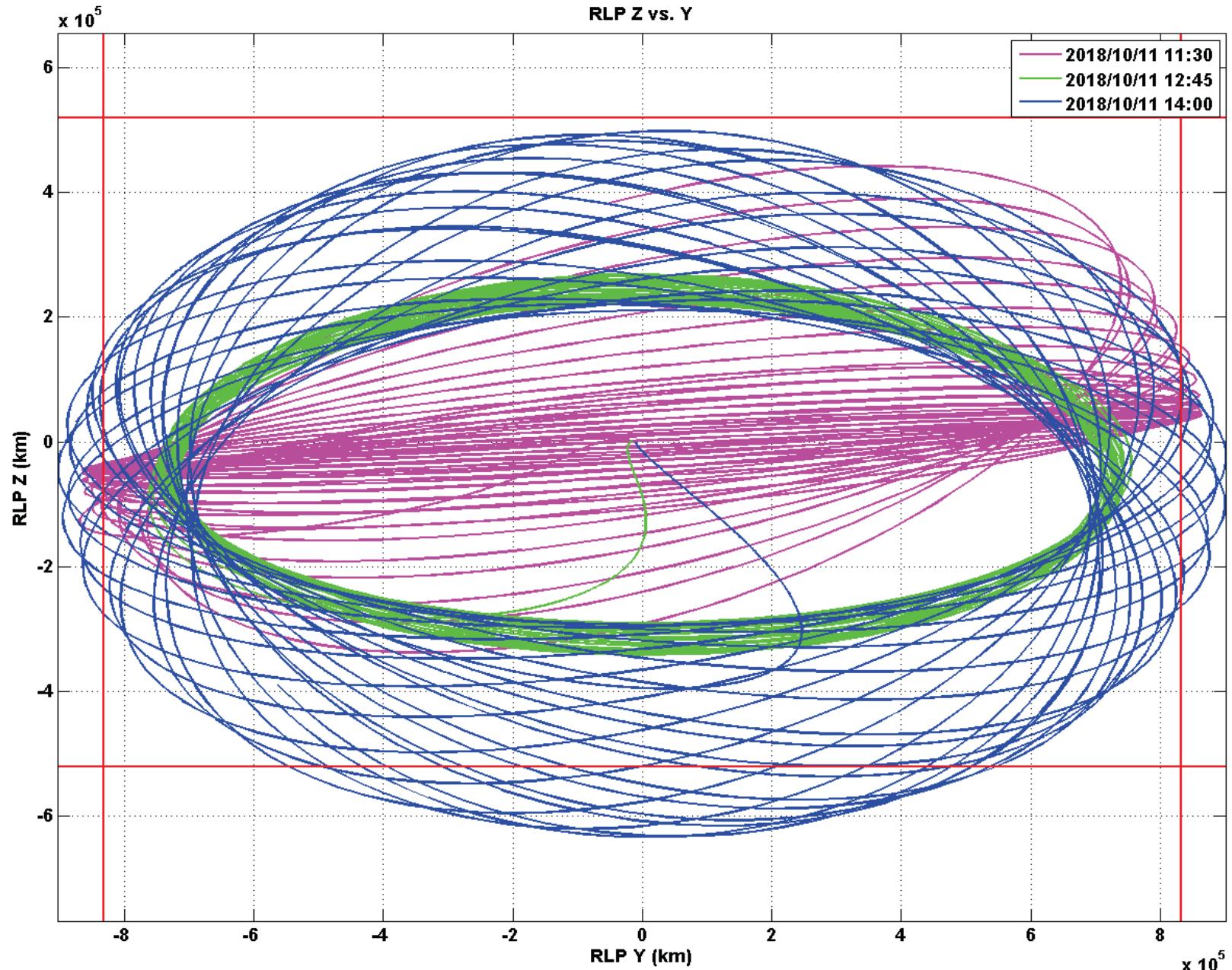




# JWST Libration Point Orbit Trajectories: Daily Behavior



Over a single launch day, the JWST orbit launch time is critical to its success. The allowable daily launch window exists within the launch window trade space of 11:30 – 14:00 UTC.





# Unconstrained Launch Window October 2018



## No Constraints

All Three Launch Flight Programs

**FP1:** Launched to a Lower Apogee

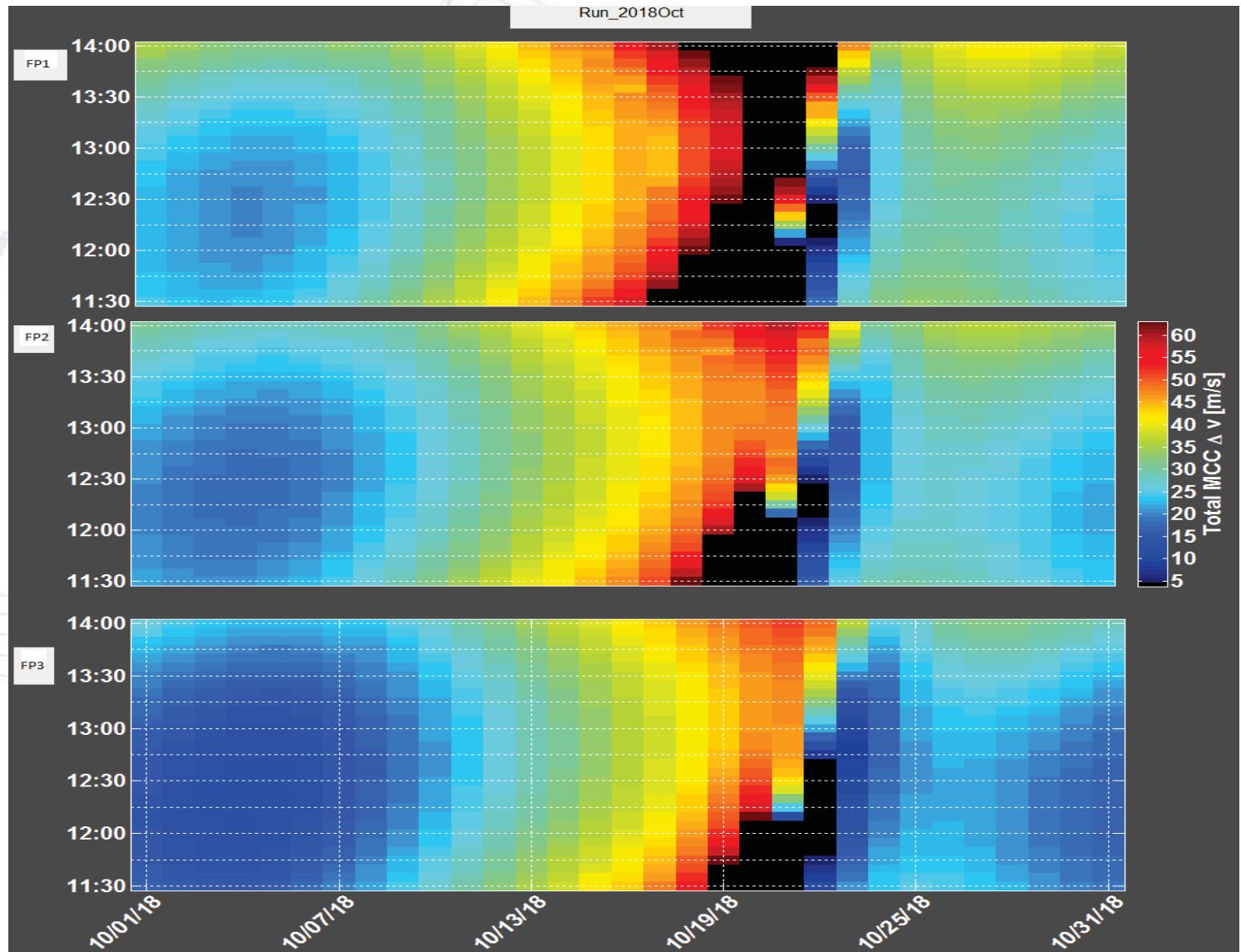
**FP2:** Launched to the Middle Apogee

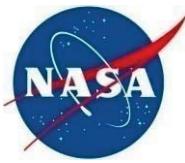
**FP3:** Launch to the Higher Apogee

**X Axis:** Launch Date

**Y Axis:** Launch Time (UTC)

**Heat Color:** MCC Total  $\Delta V$  Costs

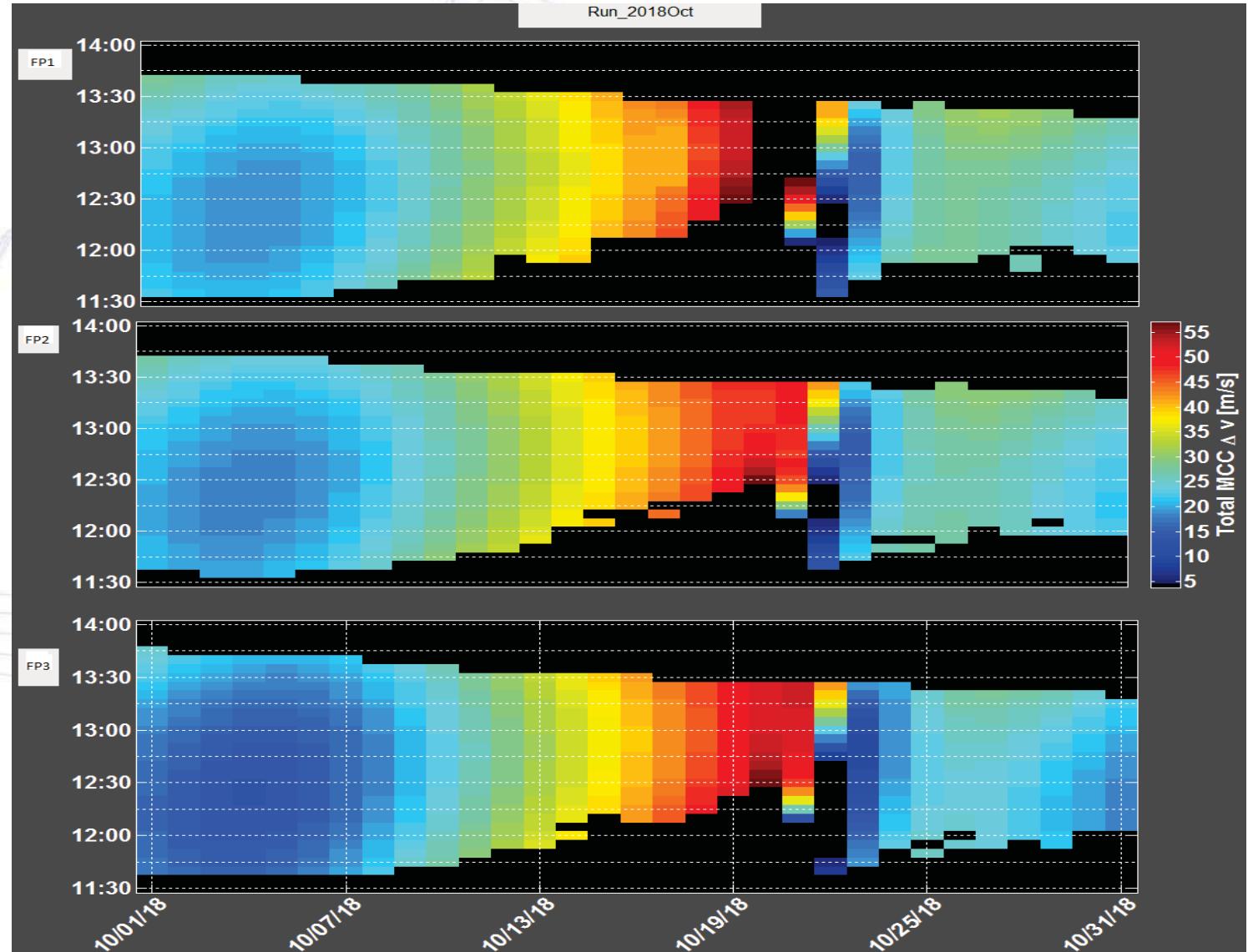




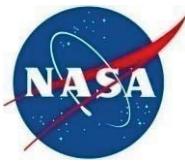
# Constrained Launch Window October 2018 (1/3)



## Enforced LPO Orbit Size Constraint Only



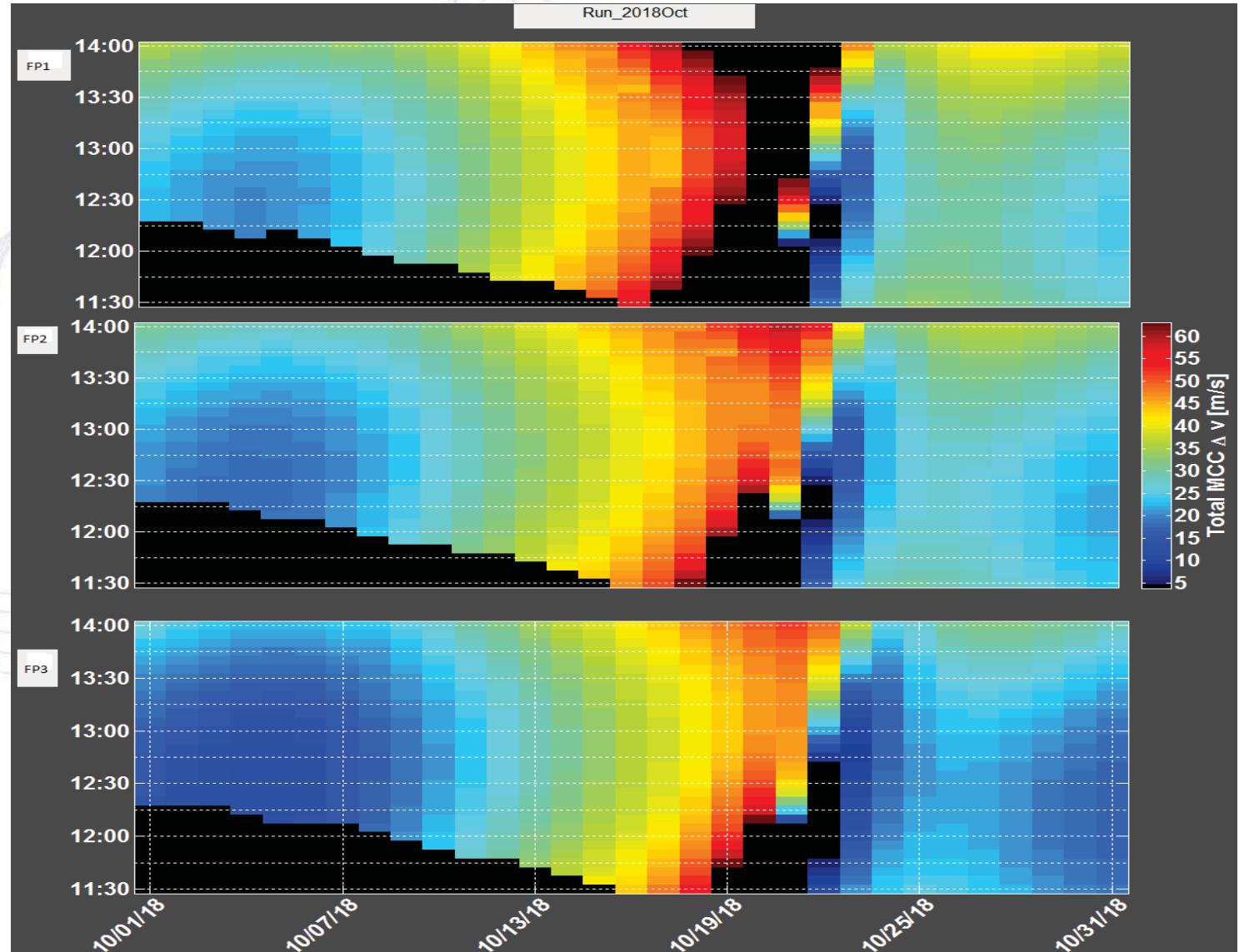
The LPO Size Constraint removes launch opportunities that are early and late in each launch day.



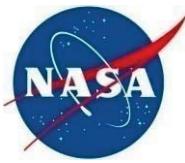
# Constrained Launch Window October 2018 (2/3)



## Enforced Earth/Moon Eclipse Constraint Only



The Earth/Moon Eclipse Constraint removes launch opportunities that are early launch times in early October 2018.



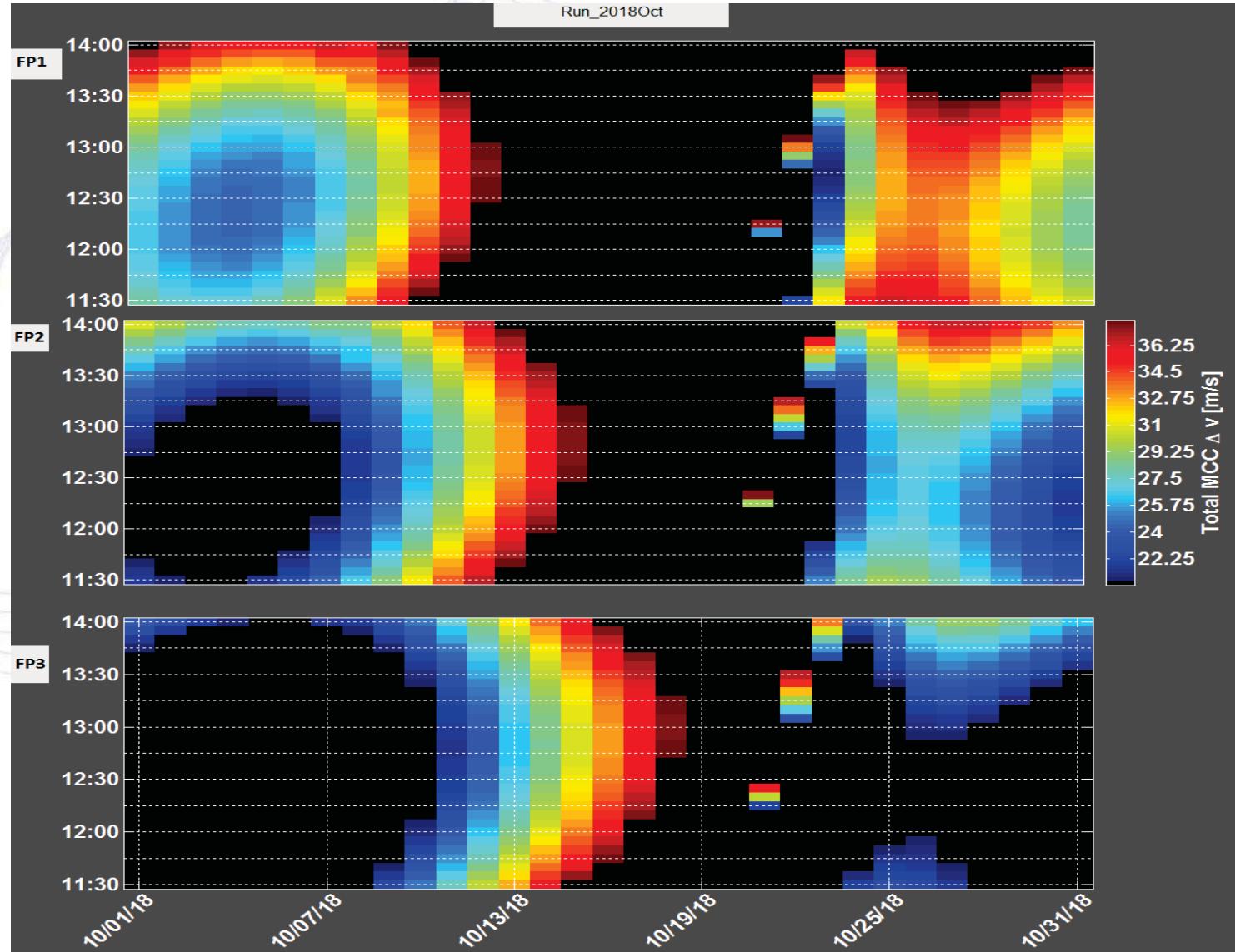
# Constrained Launch Window October 2018 (3/3)

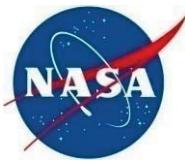


## Enforced $\Delta V$ Constraint Only

The MCC  $\Delta V$  upper limit constraint holds back launch opportunities between the first lunar quarter to the full moon.

The Heat Color is rescaled to represent the range of MCC  $\Delta V$  cost.

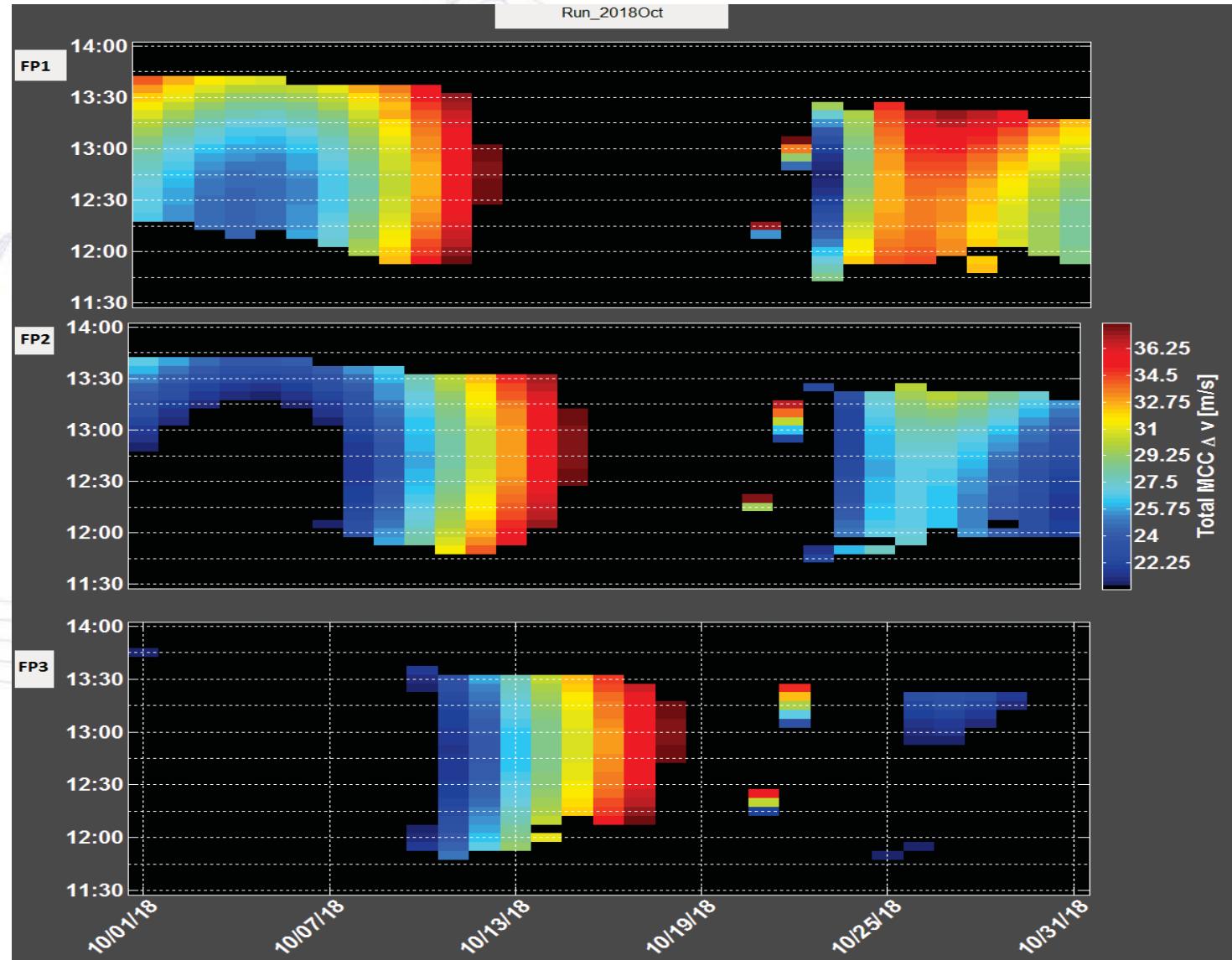


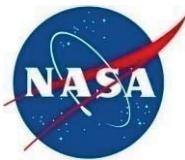


# Fully Constrained Launch Window October 2018



## Enforced All Constraints

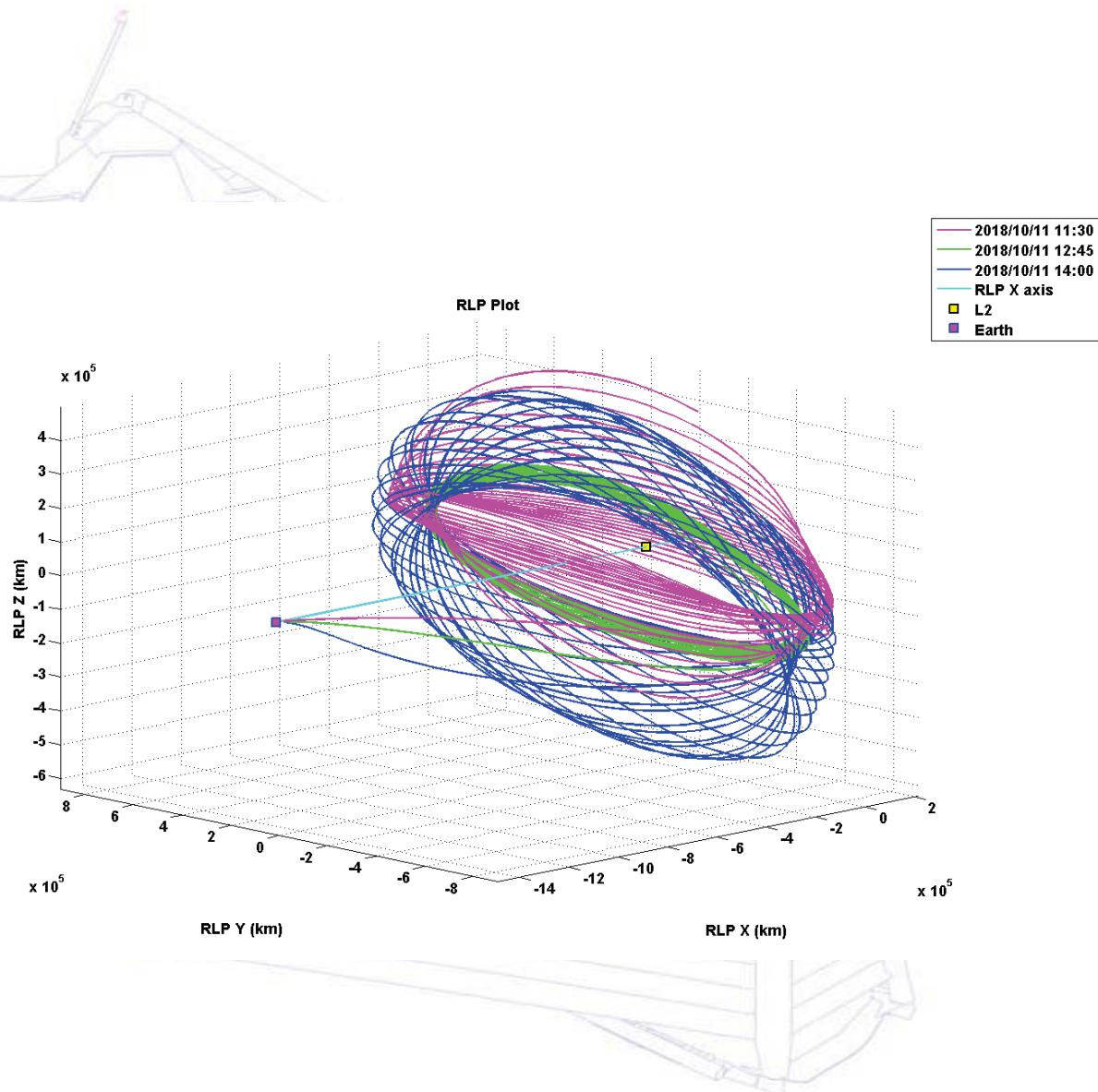




# Conclusions / Future Work



- JWST trajectory design using three MCCs provides a robust launch window for October 2018.
- By utilizing all three Ariane 5 FPs, a daily window of at least 1 hour is possible for 26 out of 31 launch days.
- The span of daily launch times result in significantly different LPO types and sizes, which may satisfy or violate requirements.
- Future Work includes refining these results with higher-fidelity modeling of launch vehicle dispersion effects to produce a more accurate  $\Delta V$  budget.



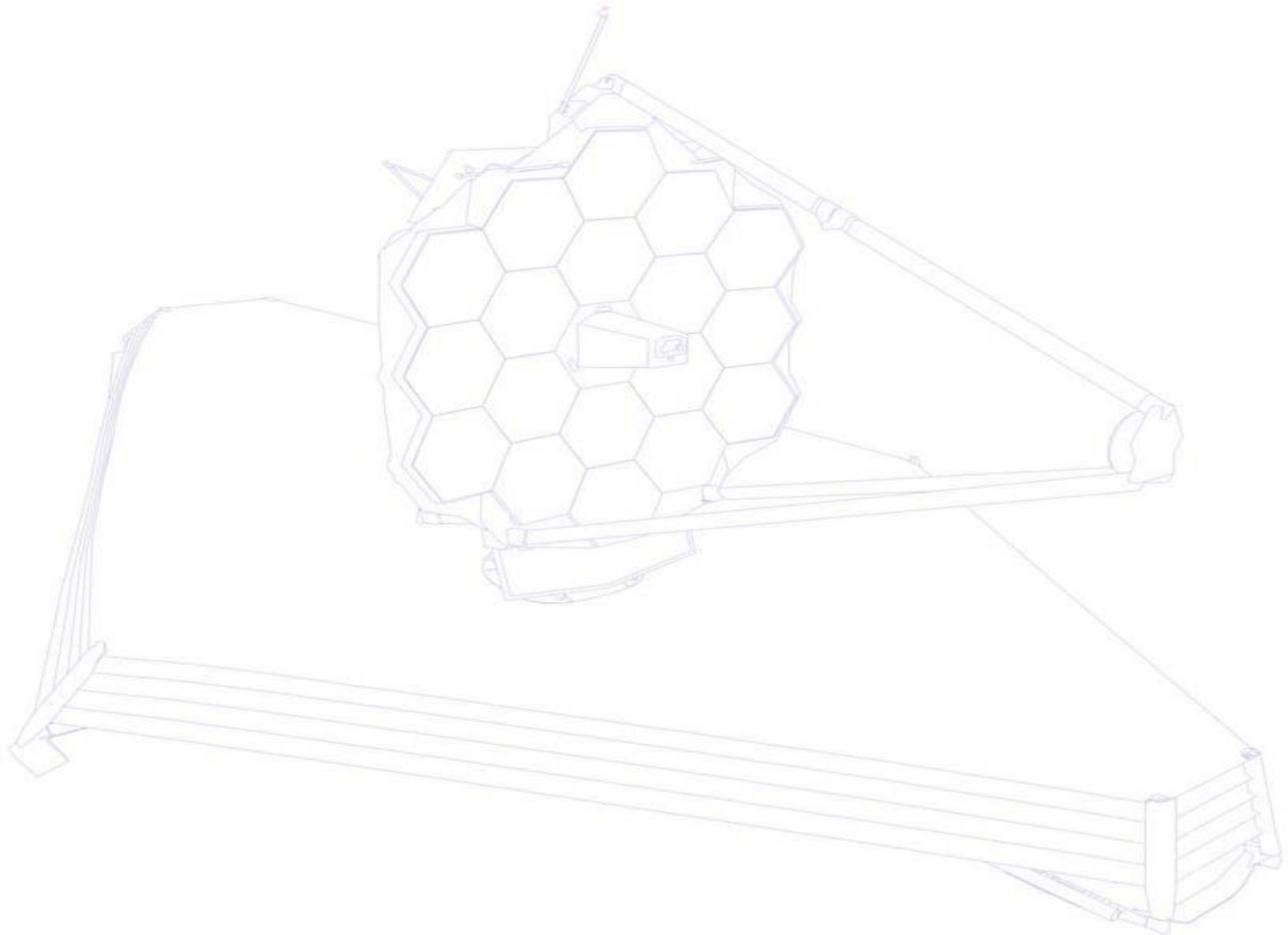


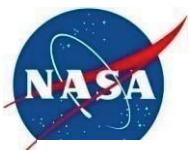
# Acknowledgements



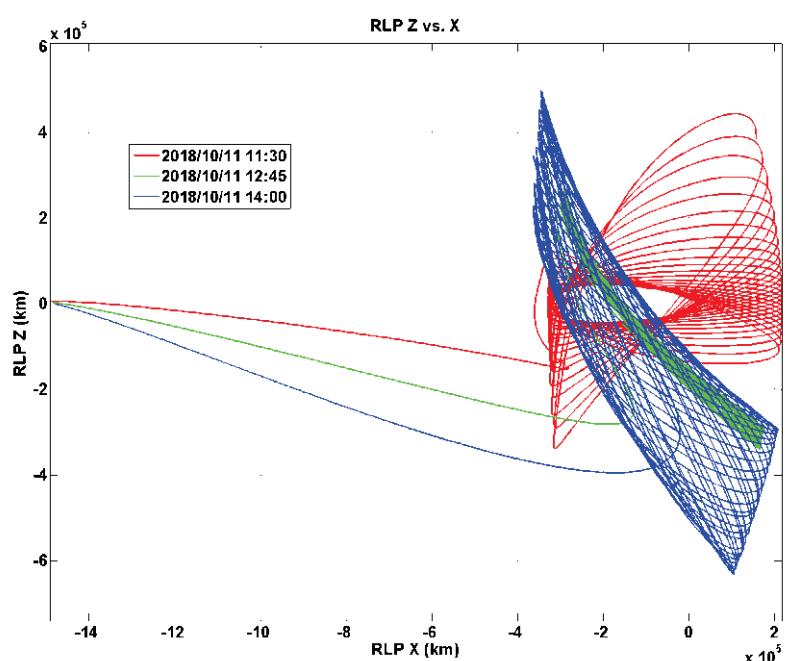
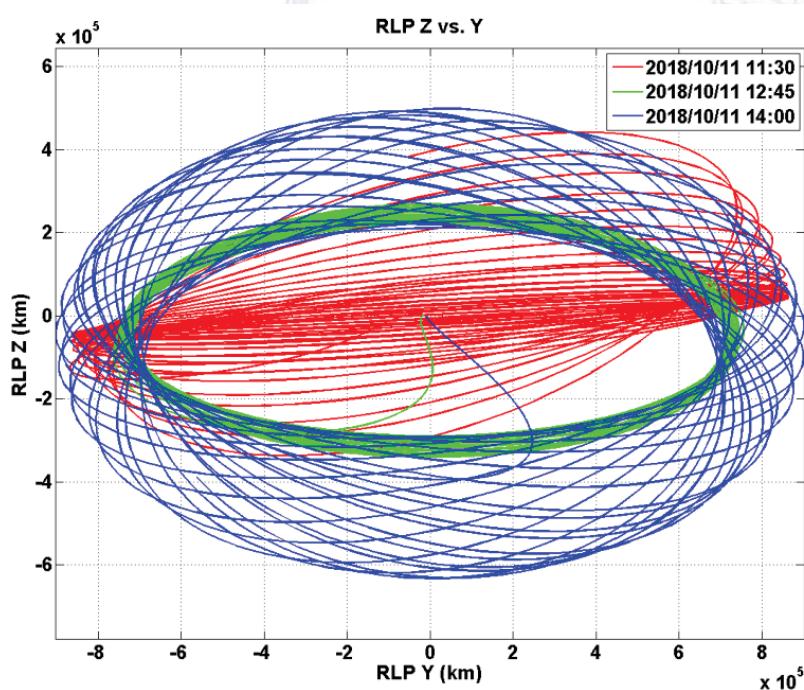
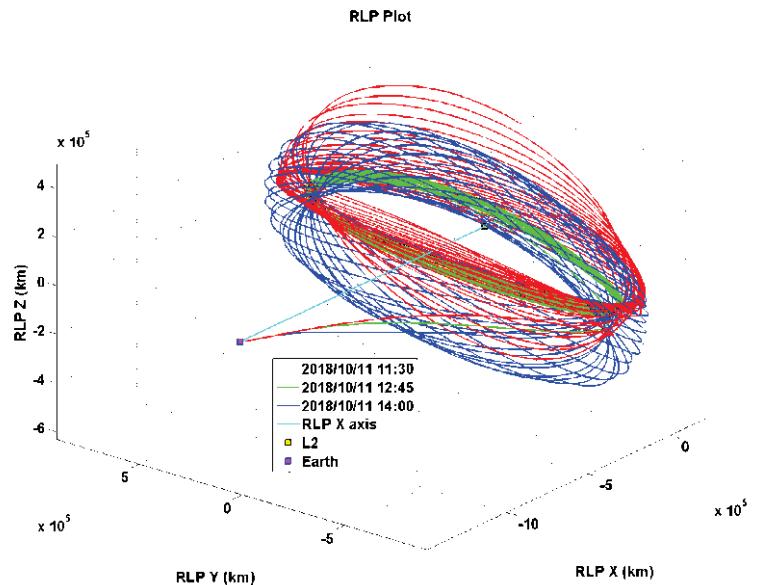
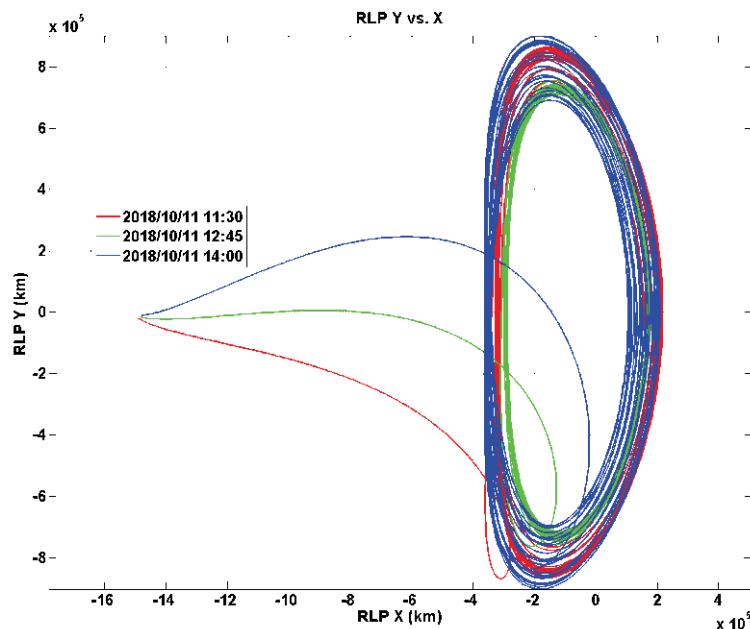
1. a.i. solutions, Inc.
2. NASA Goddard Code 595: Navigation and Mission Design Branch
  - Conrad Schiff
  - Mark Beckman
  - Leigh Forbes

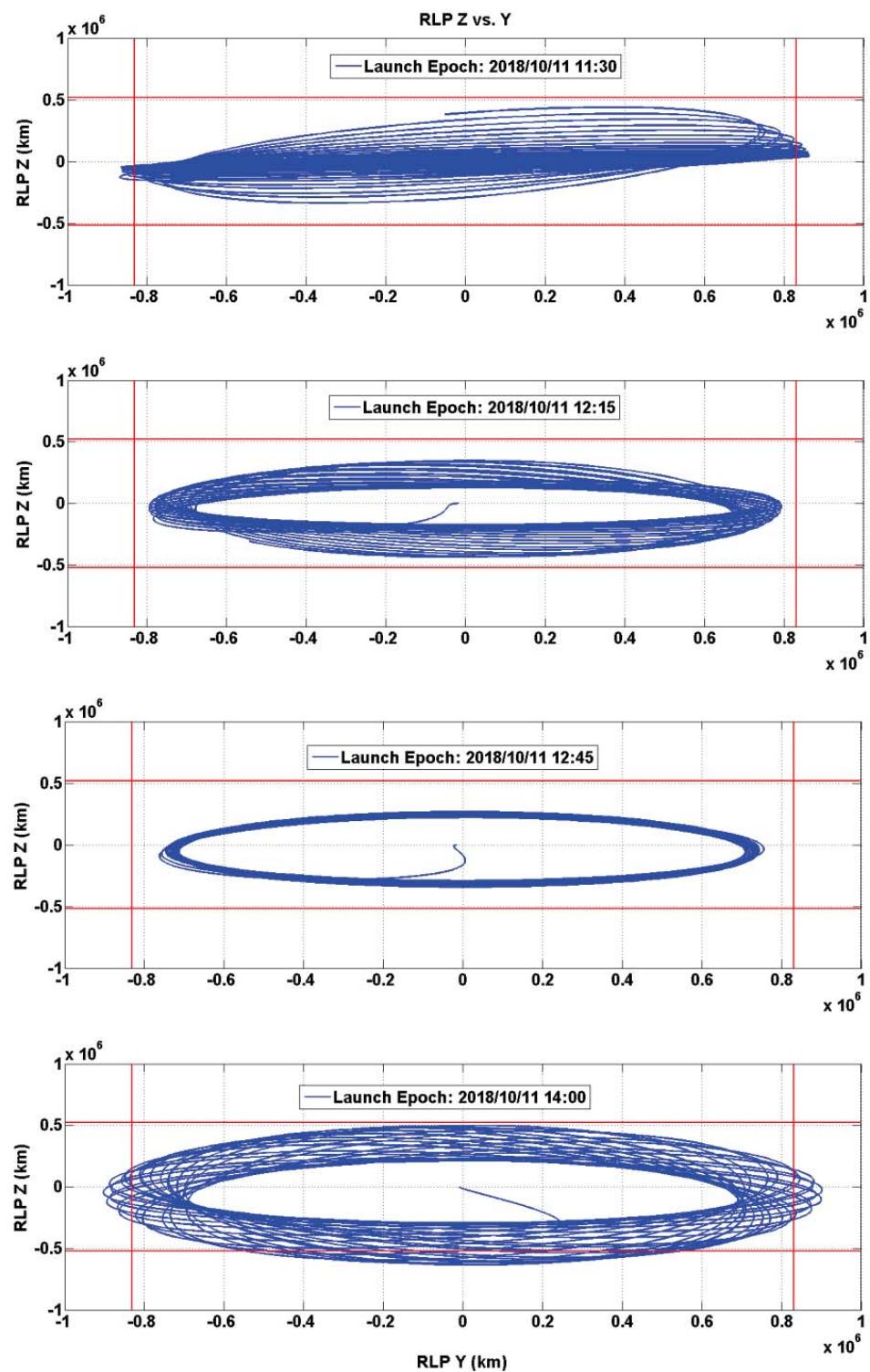
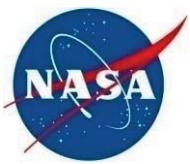
JWST Presentation Topic for the ISSFD Conference	Presenter (Affiliation)	Preliminary Session and Location
Stationkeeping Monte Carlo Simulation for the James Webb Space Telescope	Donald Dichmann (NASA GSFC)	Session 13 Thursday May 8 <sup>th</sup> , 2014 10:30 - 10:50
James Webb Space Telescope Initial Mid-Course Correction Monte Carlo Implementation using Task Parallelism	Jeremy Petersen (a.i. solutions, Inc.)	Session 13 Thursday May 8 <sup>th</sup> , 2014 10:50 - 11:10
James Webb Space Telescope Orbit Determination Analysis	Sungpil Yoon (a.i. solutions, Inc.)	Session 18 Friday May 9 <sup>th</sup> , 2014 14:10 - 14:30

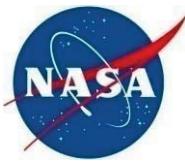




# Backup



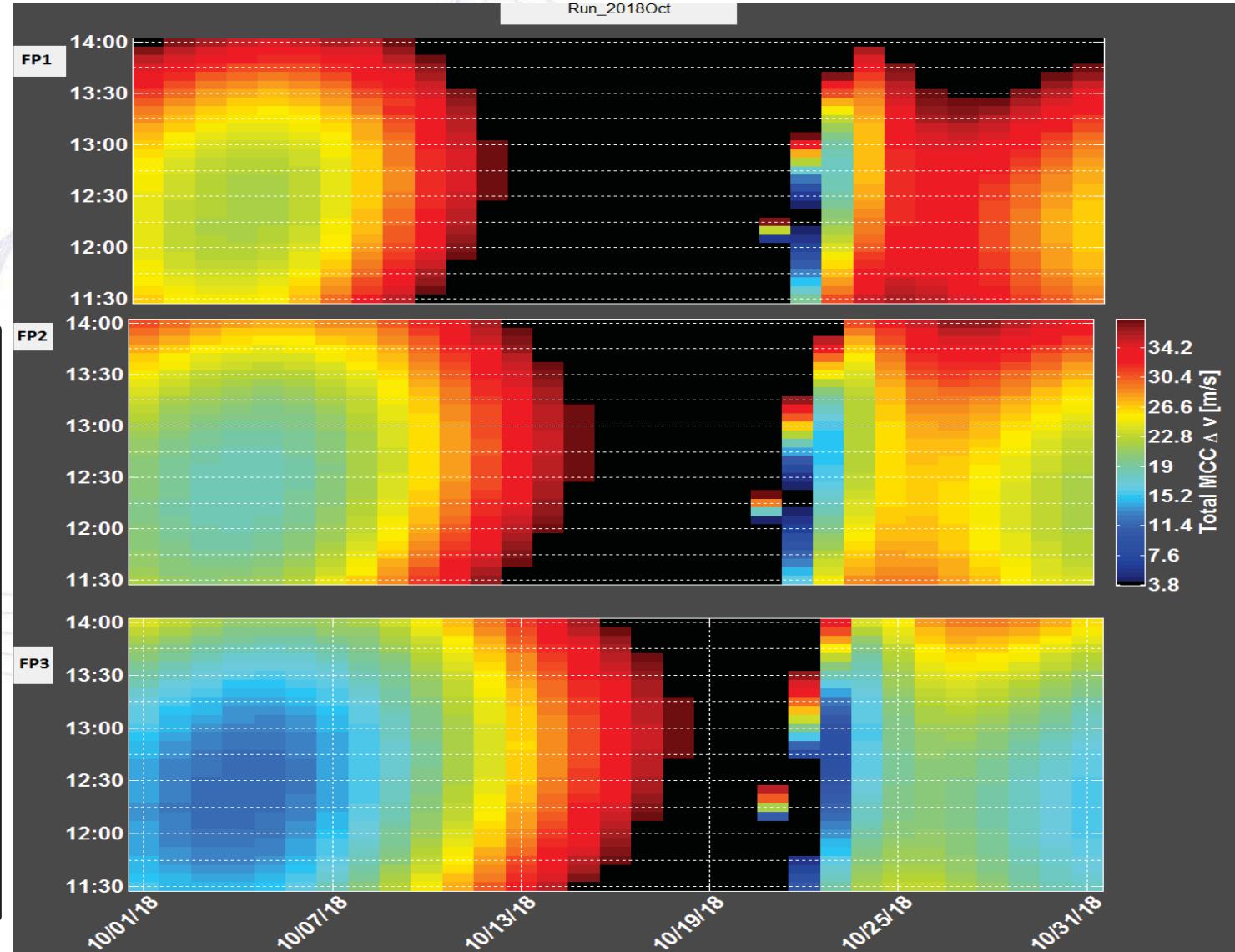




# Constrained Launch Window October 2018 (3/3)



## Enforced $\Delta V$ Constraint Only



The MCC Total  $\Delta V$  upper limit constraint holds back launch epochs between the first lunar quarter to the full moon.

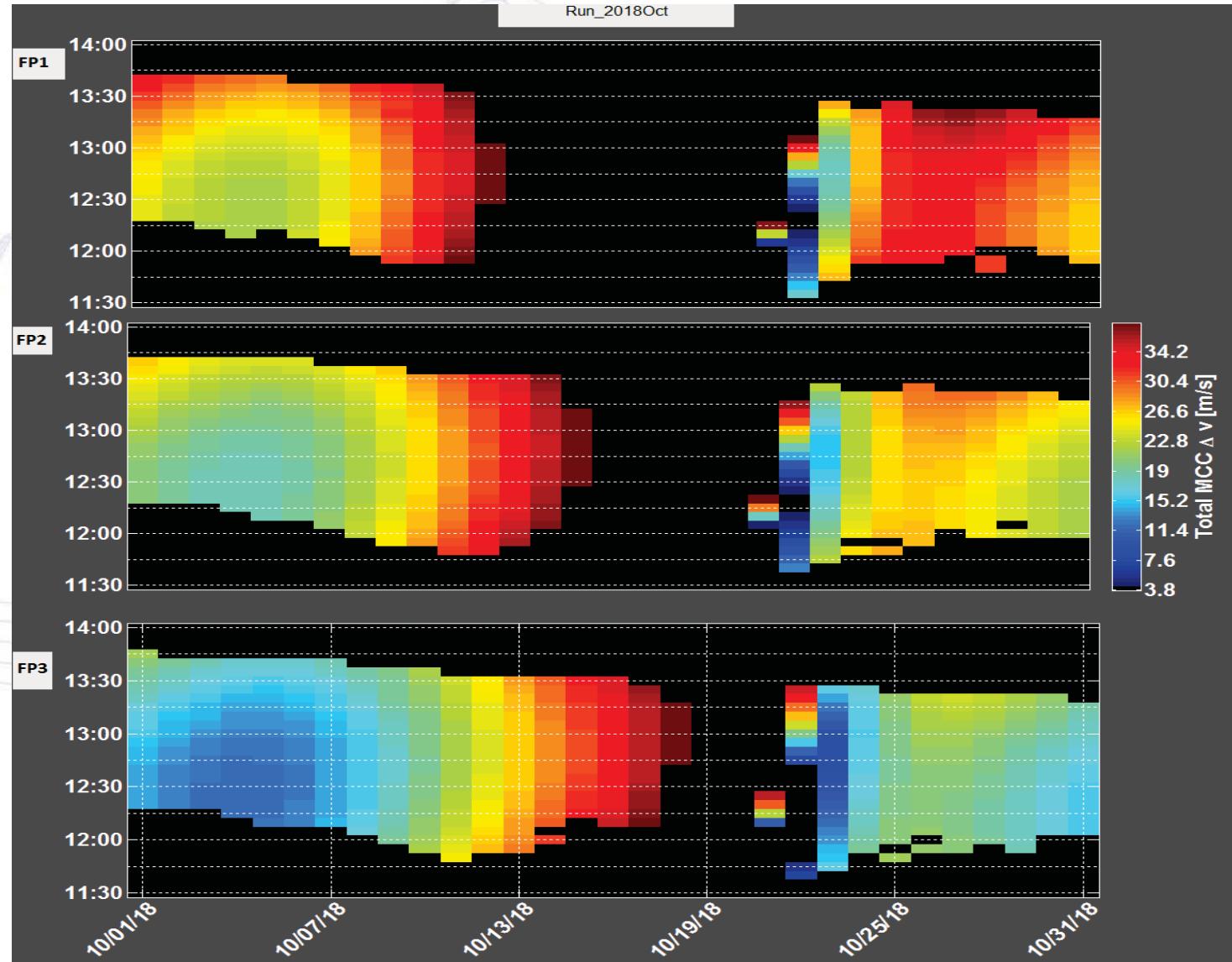
The heat plot is rescaled to demonstrate the range of MCC total  $\Delta V$  cost.

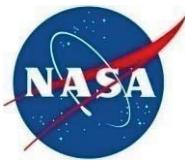


# Fully Constrained Launch Window October 2018



## Enforced All Constraints





# Methodology

